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Ionospheric Monitoring and Specification Utilizing Data from the Defense Meteorological Satellite Program

W. R. Coley
R. A. Power
P. C. Anderson
M. D. Perdue

University of Texas at Dallas
800 Campbell Road, MS/WT15
Richardson, TX 75080

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AIR FORCE RESEARCH LABORATORY
Space Vehicles Directorate
29 Randolph Rd
AIR FORCE MATERIEL COMMAND
HANSCOM AFB, MA 01731-3010

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David L. Cooke, Technical Adviser Space Weather Center of Excellence	Leonard M. Berman, Deputy Chief Space Weather Center of Excellence

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W. R. Coley
R. A. Power
P. C. Anderson
M. D. Perdue

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Activities this year have been largely devoted to the adaptation of the ground software to accommodate the very low levels of solar activity, to continued examination of the robustness of the procedures to recover for single event upsets, and to the analysis and post-mortem associated with a malfunction of the ion drift meter on the F17 spacecraft.
The low levels of solar activity have led to a significantly contracted ionosphere that resides predominantly below the satellite altitude. Such a condition leads to the dominance of H+ in regions where O+ might be expected to be the major ion. This condition has required the re-programming of some of the logic associated with ground software processing for the retarding potential analyzer (RPA) and the ion drift meter.
Extensive analysis of the F17 drift meter data, and the physical configuration of the sensor, has been undertaken following a malfunction that rendered the instrument inoperable. During this reporting period, various failure modes were investigated and compared with the temporal history of the instrument performance. The most likely failure mode has been identified and a detailed analysis has been provided to AFRL.

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SSIES-3 Post-Launch Data Analysis Report

1. INTRODUCTION

Sensors that comprise both SSIES-2 and SSIES-3 instruments have been taking data from the DMSP satellites during this reporting period. The retarding potential analyzer sweep sequence is significantly different for these two sensors and thus the adaptation of ground software to accommodate both sensors has been a prime target for our efforts. Development of robust algorithms has been aggravated by the extreme solar minimum conditions that result in the dominance of H+ over substantial portions of the orbit. This reduces the sensitivity of the angle of arrival measurements for the ion drift meter and the sensitivity of the retarding potential analyzer least-squares analysis for derivation of the in-track ion drift. However, continued adaptation of the ground software has resulted in a robust algorithm that recovers the maximum possible data.

During this solar minimum period the occurrence of single-event upsets in the main electronics package has continued. The remediation steps are now well established and always result in appropriate recovery from these events. We continue to monitor the events to confirm that the characteristic behavior does not change.

Finally, the apparent failure of the F17 ion drift meter led to extensive analysis of the instrument behavior and an exhaustive investigation of failure modes. These activities are described in more detail below.

2. SSIES PROCESSING SOFTWARE

Work continued in this period on the refinement of the ground software designed to routinely process the raw data from the SSIES-2 and SSIES-3 sensor suites. The extreme solar minimum conditions have required an ongoing effort to maintain the robustness of the algorithms for both sensors and coupled with the failure of the F17 ion drift meter, continuous evaluation of the derived geophysical parameters has been required. The next generation software for SSIES-3 was delivered in August, 2009.

In this software update several issues were addressed associated with the relative abundance of H+ around the orbit and with performance anomalies in the instrument operations.

In November, 2008 a command reset was required to restore the digital status words containing the sensitivity levels of the electrometers. Prior to this reset the derived total ion density would reach prematurely saturated values. Subsequently the appearance of plasma at equatorial latitudes that was completely dominated by H+ lead to marginal performance of the ion drift meter, which needed to be flagged in a quality parameter, and to the malfunction of the least-squares analysis in the RPA, which required a re-work of the ground software. After appropriate testing and analysis a software patch for the SSIES ground software was delivered to AFRL in April, 2009.

Figure 1 shows the geophysical parameters derived from the F17 SSIES-3 sensor for a day in October, 2009. For SSIESE-3 the parameters are derived with ½ second resolution (8 times that previously available from SSIES-2). The top panel shows ion and electron temperatures around the orbit with 1-second resolution.

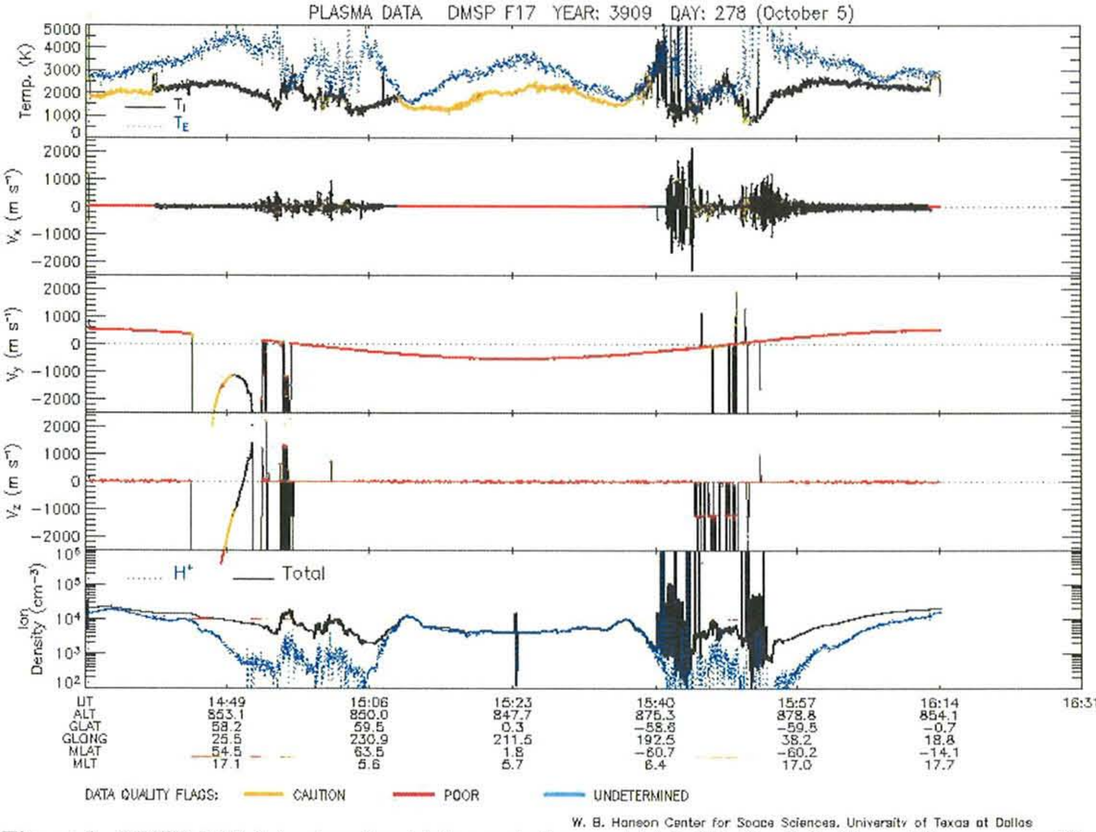

Figure 1. DMSP F17 data showing high-resolution and high fidelity definition of ion composition and temperature in a H+ dominant plasma

Notice that the H+ is dominant ion throughout the low and middle latitude region and in such circumstances it is not possible to retrieve the ram ion drift from the RPA. At high latitudes in the southern hemisphere the solar zenith angle at the spacecraft is very large and the ion density drops to very low values in darkness. Under these conditions appropriate filtering of the data is required to record the total ion concentration.

3. F17 ION DRIFT METER FAILURE

On 6/23/09 the normal telemetry outputs from the F17 SSIES Ion Drift Meter (IDM) ceased. The data showed an abrupt loss of signal from the DM electrometers, indicating that the collector plates were collecting no current. It was subsequently discovered that the electrometers and difference amplifiers are responsive for small periods at specific locations in each orbit. Figure 2 shows in the upper panel, the normally tracked electrometer outputs across the failure point and in the lower panel the typically observed behavior of the electrometer outputs at specific locations during each orbit following the failure.

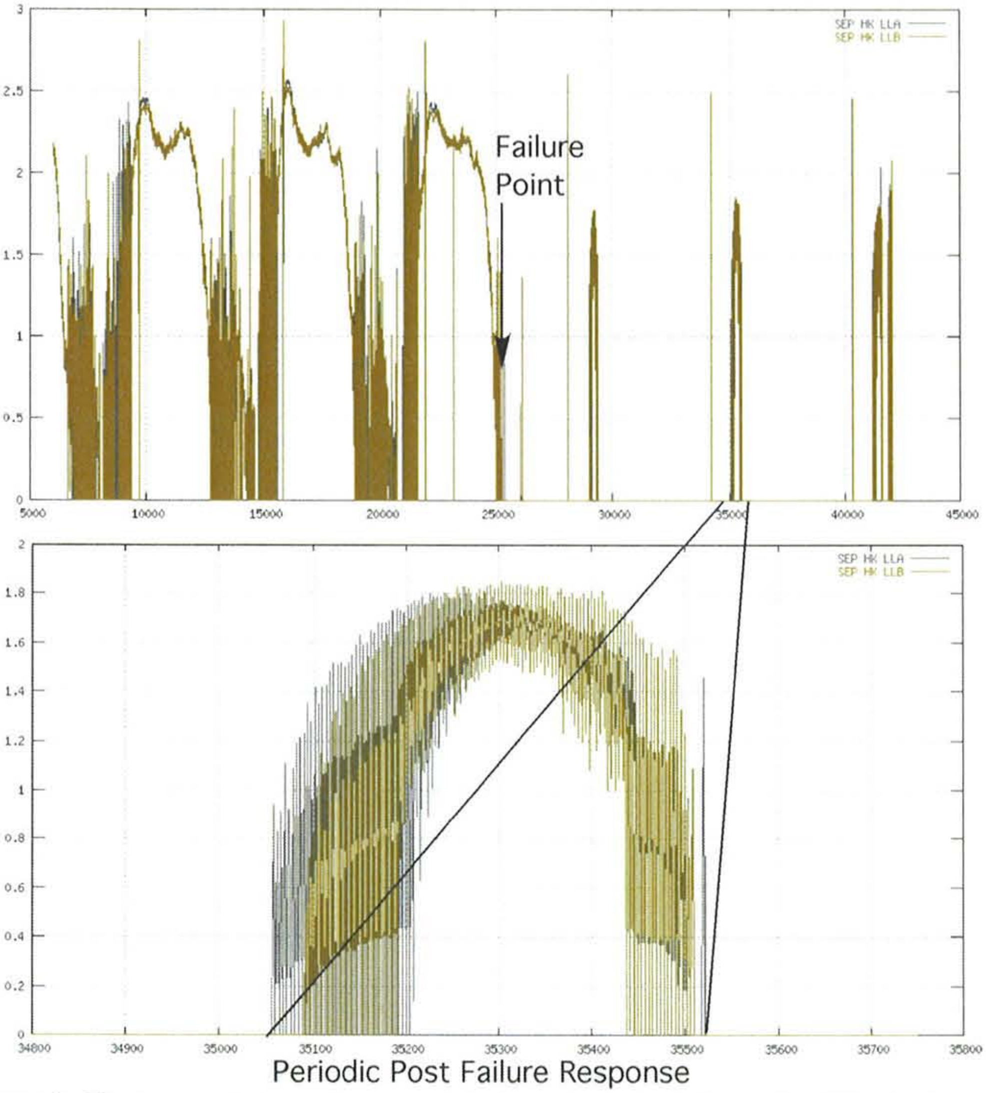

Figure 2. The top panel shows the normal electrometer outputs for each orbit prior to and following the failure point. The lower panel shows the periodic response during one orbit following the failure. Each output is shown as a function of UT in seconds.

There are short intervals in each orbit where the electrometer outputs return positive ion currents albeit at lower levels than expected during normal operations. During these intervals comparable signals to the electrometers in all collector modes are seen. A fault in a single electrometer or front-end switch would affect one signal at all times and likely not affect the other signal at all. These intervals thus demonstrated demonstrate that the electrometers and difference amplifier are functioning normally. Thus, the source of the failure lies in the inability of the ion collector segments to receive the ambient ion current and we concluded that the fault lies in the sensor head itself. After an extensive analysis we can determine two possible failure locations

1. Anomalously Large Drift Repeller Potential

Subsequent analysis of observed ion current removed this failure location as a sensible option

2. Failure of the Supressor Grid

This failure can be produced in one of three ways
A) The capacitor between the grid and ground is shorted.
B) The resistor failed open.
C) A mechanical (physical) short to of the suppressor grid to ground.
The first two possibilities require the failure of robust and formerly long-lived electronic components and the probability of such a failure was thought to be small compared to the mechanical failure that would allow the third option. We concluded that a likely short between the suppressor grid and the forward grounded grid is the most likely failure consistent with the observed instrument behavior. The grids are woven wire and it is possible that a single wire strand can complete a short to a neighboring grid. Such a short would require a stress fracture, which has never occurred in similar devices constructed over the past 30 years, or mechanical destruction of the grid due to perhaps to meteoric impact.
A full report detailing the analysis and conclusions concerning the F17 ion drift meter failure was submitted to AFRL in September 2009.

4. MISCELLANEOUS ACTIVITIES

During this period we have continued to populate the DMSP data website to enable scientists at UTD and AFRL to readily examine the SSIES data. For the present solar minimum conditions, where the analysis procedures have been tested to their maximum capability, it has been particularly helpful. UTD has also continued to provide support services to AFRL as requested during this period. These include verification of single event upsets and responses to other performance and data analysis anomalies.

5. WORK PLANNED FOR THE NEXT PERIOD

During the coming year we expect that the restrictive analysis procedures, imposed to produce the best data during solar minimum, will need to be relaxed in order to retrieve that maximum possible data. We will continue to examine the sensor performance and update the ground software as necessary to accommodate these changing conditions.
We expect that software modifications will be required to accommodate the on-orbit performance of SSIES on F18. Comparisons between the SSIES sensor performance on the different DMSP satellites will be undertaken to verify the analysis routines for each one.
Continued monitoring of the data to verify the operation of the sensors and the associated sensor potential circuits will be routinely undertaken as will the occurrence of single event upsets and the remedial operations to mitigate their effects.
We will continue to provide support to AFRL to and be responsive to SSIES performance issues as they arise.

6. SCIENTISTS AND ENGINEERS CONTRIBUTING TO THIS RESEARCH

W. R. Coley	Research Scientist
R. A. Heelis	Principal Investigator
M. D. Perdue	Research Engineer/Scientist
R. A. Power	Project Supervisor